

Atty. Dkt. No. 200311960-1AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application.

- 1 1. (Currently amended) A computer implemented method of determining lower and  
2 upper bounds for a minimum cost comprising the steps of:  
3 solving an integer program using a relaxation of binary variables to  
4 determine the lower bound, the binary variables having values between zero  
5 and one comprising a first subset;  
6 for the binary variables in the first subset and until no binary variables  
7 remain in the first subset, iteratively performing the steps of:  
8 rounding up a first binary variable having a lowest ratio of a cost  
9 penalty to a performance reward; and  
10 until no binary variables remain in a second subset, iteratively  
11 performing the steps of:  
12 determining the binary variables in the first subset that may  
13 be rounded down without violating a performance constraint,  
14 thereby forming the second subset;  
15 rounding down one or more second binary variables in the  
16 second subset having a zero performance reward; and  
17 rounding down a third binary variable in the second subset  
18 having a highest ratio of a cost reward to the performance  
19 reward if none of the binary variables in the second subset have  
20 the zero performance reward; and  
21 determining the upper bound according to the binary variables having  
22 binary values.
- 1 2. (Currently amended) The computer implemented method of claim 1 wherein the  
2 integer program comprises the performance constraint and an objective of minimizing  
3 a cost.

Atty. Dkt. No. 200311960-1

1 3. (Currently amended) The computer implemented method of claim 1 wherein the  
2 integer program models a data placement problem.

1 4. (Currently amended) The computer implemented method of claim 3 wherein the  
2 data placement problem seeks to minimize ~~the~~ cost of placing data objects onto  
3 nodes of a distributed storage system while meeting a performance requirement for a  
4 workload.

1 5. (Currently amended) The computer implemented method of claim 1 wherein the  
2 step of rounding up the first binary variable within the first subset further comprises  
3 calculating the cost penalty and the performance reward.

1 6. (Currently amended) The computer implemented method of claim 5 wherein the  
2 step of rounding down the one or more second binary variables within the second  
3 subset further comprises calculating the performance reward.

1 7. (Currently amended) The computer implemented method of claim 6 wherein the  
2 step of rounding down the third binary variable within the second subset further  
3 comprises calculating the cost reward.

1 8. (Currently amended) A computer implemented method of determining bounds for  
2 a minimum cost comprising the steps of:  
3 solving an integer program using a relaxation of binary variables to  
4 determine a lower bound for the minimum cost, the relaxation allowing the  
5 binary variables to take values over the range of zero to one, a first subset of  
6 the binary variables comprising the binary variables having values between  
7 zero and one, the integer program modeling a data placement problem which  
8 seeks to minimize a cost of placing data objects onto nodes of a distributed  
9 storage system while meeting a performance requirement for a workload;  
10 until no binary variables remain in the first subset, iteratively performing  
11 the steps of:

Atty. Dkt. No. 200311960-1

12 calculating a cost penalty and a performance reward for each of the  
13 binary variables in the first subset;  
14 rounding up a first binary variable having a lowest ratio of the cost  
15 penalty to the performance reward;  
16 until no binary variables remain in a second subset, iteratively  
17 performing the steps of:  
18 determining the binary variables in the first subset that may  
19 be rounded down without violating the performance  
20 requirement, thereby forming the second subset;  
21 calculating a cost reward and the performance reward for  
22 each of the binary variables in the second subset;  
23 rounding down one or more second binary variables in the  
24 second subset having a zero performance reward;  
25 rounding down a third binary variable in the second subset  
26 corresponding to a highest ratio of a cost reward to the  
27 performance reward if none of the binary variables in the  
28 second subset have the zero performance reward; and  
29 determining an upper bound for the minimum cost according to the binary  
30 variables having binary values.

1 9. (Currently amended) The computer implemented method of claim 8 wherein the  
2 integer program further comprises a storage constraint.

1 10. (Currently amended) The computer implemented method of claim 9 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:  
4 determining a particular node which uses a maximum amount of storage  
5 within any evaluation interval; and  
6 allocating the maximum amount of storage on all nodes for all evaluation  
7 intervals.

Atty. Dkt. No. 200311960-1

1 11. (Currently amended) The computer implemented method of claim 9 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum amount of storage for each node within any  
5 evaluation interval; and  
6 allocating the maximum amount of storage on each node for all evaluation  
7 intervals.

1 12. (Currently amended) The computer implemented method of claim 8 wherein the  
2 integer program further comprises a replica constraint.

1 13. (Currently amended) The computer implemented method of claim 12 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum number of replicas for any data object within any  
5 evaluation interval; and  
6 placing the maximum number of replicas for all data objects for all  
7 evaluation intervals.

1 14. (Currently amended) The computer implemented method of claim 12 wherein the  
2 step of determining the upper bound for the minimum cost further comprises the steps  
3 of:

4 determining a maximum number of replicas for each data object within  
5 any evaluation interval; and  
6 placing the maximum number of replicas for each data object for all  
7 evaluation intervals.

1 15. (Original) A computer readable memory comprising computer code for  
2 implementing a method of determining bounds for a minimum cost, the method of  
3 determining the bounds for the minimum cost comprising the steps of:  
4 solving an integer program using a relaxation of binary variables to

Atty. Dkt. No. 200311960-1

5 determine a lower bound for the minimum cost, the integer program  
6 comprising a performance constraint and an objective of minimizing a cost,  
7 the binary variables having values between zero and one comprising a first  
8 subset;  
9 for the binary variables within the first subset and until no binary variables  
10 remain in the first subset, iteratively performing the steps of:  
11 rounding up a first binary variable having a lowest ratio of a cost  
12 penalty to a performance reward; and  
13 until no binary variables remain in a second subset, iteratively  
14 performing the steps of:  
15 determining the binary variables in the first subset that may  
16 be rounded down without violating the performance constraint,  
17 thereby forming the second subset;  
18 rounding down one or more second binary variables in the  
19 second subset having a zero performance reward; and  
20 rounding down a third binary variable in the second subset  
21 having a highest ratio of a cost reward to the performance  
22 reward if none of the binary variables in the second subset have  
23 the zero performance reward; and  
24 determining an upper bound for the minimum cost according to the binary  
25 variables having binary values.

1 16. (Original) The computer readable memory of claim 15 wherein the integer  
2 program models a data placement problem.

1 17. (Currently amended) The computer readable memory of claim 16 wherein the  
2 data placement problem seeks to minimize ~~at~~ the cost of placing data objects onto  
3 nodes of a distributed storage system while meeting a performance requirement for a  
4 workload.

1 18. (Currently amended) The computer readable memory of claim 15 wherein the

Atty. Dkt. No. 200311960-1

2 step of rounding up the first binary variable within the first subset further comprises  
3 calculating the cost penalty and the performance reward.

1 19. (Currently amended) The computer readable memory of claim 18 wherein the  
2 step of rounding down the one or more second binary variables within the second  
3 subset further comprises calculating the performance reward.

1 20. (Currently amended) The computer readable memory of claim 19 wherein the  
2 step of rounding down the third binary variable within the second subset further  
3 comprises calculating the cost reward.

1 21. (Original) A computer readable memory comprising computer code for  
2 implementing a method of determining bounds for a minimum cost, the method of  
3 determining the bounds for the minimum cost comprising the steps of:  
4 solving an integer program using a relaxation of binary variables to  
5 determine a lower bound for the minimum cost, the relaxation allowing the  
6 binary variables to take values over the range of zero to one, a first subset of  
7 the binary variables comprising the binary variables having values between  
8 zero and one, the integer program modeling a data placement problem which  
9 seeks to minimize a cost of placing data objects onto nodes of a distributed  
10 storage system while meeting a performance requirement for a workload;  
11 until no binary variables remain in the first subset, iteratively performing  
12 the steps of:  
13 calculating a cost penalty and a performance reward for each of the  
14 binary variables in first the subset;  
15 rounding up a first binary variable having a lowest ratio of the cost  
16 penalty to the performance reward;  
17 until no binary variables remain in a second subset, iteratively  
18 performing the steps of:  
19 determining the binary variables in the first subset that may  
20 be rounded down without violating the performance

Atty. Dkt. No. 200311960-1

21 requirement, thereby forming the second subset;  
22 calculating a cost reward and the performance reward for  
23 each of the binary variables in the second subset;  
24 rounding down one or more second binary variables in the  
25 second subset having a zero performance reward;  
26 rounding down a third binary variable in the second subset  
27 corresponding to a highest ratio of a cost reward to the  
28 performance reward if none of the binary variables in the  
29 second subset have the zero performance reward; and  
30 determining an upper bound for the minimum cost according to the binary  
31 variables having binary values.

1 22. (Original) The computer readable memory of claim 21 wherein the integer  
2 program further comprises a storage constraint.

1 23. (Original) The computer readable memory of claim 22 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of:  
3 determining a particular node which uses a maximum amount of storage  
4 within any evaluation interval; and  
5 allocating the maximum amount of storage on all nodes for all evaluation  
6 intervals.

1 24. (Original) The computer readable memory of claim 22 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of:  
3 determining a maximum amount of storage for each node within any  
4 evaluation interval; and  
5 allocating the maximum amount of storage on each node for all evaluation  
6 intervals.

1 25. (Original) The computer readable memory of claim 21 wherein the integer  
2 program further comprises a replica constraint.

Atty. Dkt. No. 200311960-1

1 26. (Original) The computer readable memory of claim 25 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of;  
3 determining a maximum number of replicas for any data object within any  
4 evaluation interval; and  
5 placing the maximum number of replicas for all data objects for all  
6 evaluation intervals.

1 27. (Original) The computer readable memory of claim 25 wherein the step of  
2 determining the upper bound for the minimum cost further comprises the steps of;  
3 determining a maximum number of replicas for each data object within  
4 any evaluation interval; and  
5 placing the maximum number of replicas for each data object for all  
6 evaluation intervals.